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The potential of different countermeasures to prevent injuries with high risk of health loss among bicyclists in Sweden

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ABSTRACT

Objective: As bicyclists account for the largest share of serious injuries in Sweden, focus to improve safety for bicyclists is needed. While knowledge about fatal bicycle crashes is rather extensive, the number of studies that have investigated non-fatal injuries is still rather limited. The aim of this study was to estimate the potential of different countermeasures to reduce crashes resulting in injuries with high risk of health-loss among cyclists in Sweden. A further aim was to describe the residual—that is, crashes that were not considered to be addressed by the analyzed countermeasures.

Methods: A sample of individuals with specific injury diagnoses was drawn from the Swedish national crash database Strada. A survey form was used to collect additional information about the crash and the health-related outcomes. The potential of countermeasures currently included in the Swedish Safety Performance Indicators, as well as of countermeasures that could be described as "existing but not fully implemented" was assessed. The overall potential of all countermeasures assessed was calculated, giving a grand total without double counting. Cases that were considered not to be addressed by any of the countermeasures included (i.e., the residual crashes) were described in more detail.

Results: The current Swedish Safety Performance Indicators that relate to safe cycling addressed 22% of crashes. Improved maintenance by deicing and removal of snow from bicycle infrastructure was found to have the highest potential (8%), followed by improved crashworthiness of passenger cars (5%) and safer bicycle crossings (4%). The potential for existing but not fully implemented safety improvements was 56%. The greatest potential was found for Autonomous Emergency Braking with cyclist detection for passenger cars (12%), followed by studded winter tyres for bicycles (12%), and improved maintenance on non-bicycle infrastructure (11%). In total, taking double counting into consideration, all safety improvements could address 64% of all crashes. Among the residual crashes, the majority (69%) were single bicycle crashes of which most were related to wheel locking during braking and losing balance at low speed or stationary.

Conclusions: Compared with fatal crashes that involve a majority of bicycle-car crashes, the crashes leading to health-loss are mostly single bicycle crashes. Therefore, innovation and development of additional countermeasures to improve safety for bicyclists should focus on single bicycle crashes.

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Introduction

Cycling for transportation is associated with benefits for individuals' health, as well as for the environment (Hartog et al. 2011; Oja et al. 2011; Holm et al. 2012; Rojas-Rueda et al. 2013). On an average day, 8% of Swedes travel by bicycle, however there are great seasonal and geographical variations. The majority of bicycle trips (71%) are made within larger cities, and during April-September. The distribution of number of daily bicycle trips is similar across different age groups, with the exception of people over 65 years who account for 10% of the number of bicycle trips (Swedish Transport Administration 2019).

In case of a crash, bicyclists are vulnerable road users (VRU) with higher risk for injuries compared with car occupants (Nilsson et al. 2017). According to Swedish national statistics, bicyclists account for the largest share of seriously injured in the road transport system, 47% in 2017, corresponding to around 2000 injured (Swedish Transport Administration 2018).

In 2007, Sweden decided on an interim target to reduce fatalities and serious injuries in the road transport system by 50 and 25%, respectively, by 2020 (Swedish Transport Administration 2018). To monitor the development of the safety of the road transport system, a set of safety performance indicators (SPIs) were developed to facilitate the work

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toward the interim targets. Three of the SPIs relate to cycling; Bicycle helmet usage, Safe bicycle crossings, Good quality maintenance of bicycle paths. Safe bicycle crossing are defined as bicycle crossing with speed-calming measures resulting in 85 percentile driving speed of 30 kph or less.

As bicyclists account for the largest share of serious injuries in Sweden, focus to improve safety for bicyclists is needed. While knowledge about fatal bicycle crashes is rather extensive, the number of studies that have investigated non-fatal injuries is still rather limited. Crashes involving motor vehicles have been reported to account for 63–92% of fatal bicycle crashes (Nicaj et al. 2009; Gaudet et al. 2015; Bil et al. 2016). Kullgren et al. (2019) analyzed the potential for different countermeasures to address fatal bicycle crashes. They found that the majority of fatal injuries were head injuries (70%). The majority of bicycle crashes were collisions with motor vehicles, most often passenger cars (46%). Therefore, the potential of different safety systems in cars (mainly Autonomous Emergency Braking, AEB) to prevent fatal bicycle crashes was found to be large, 62%.

Based on hospital-reported data, it is previously known that approximately 80% of bicycle crashes in Sweden are single bicycle crashes (Swedish Transport Administration 2014). In 2014, the Swedish Transport Administration estimated the potential of a number of different countermeasures to address bicycle crashes and injuries, for example, improved maintenance of bicycle infrastructure, the use of bicycle helmets, adjustment of kerbstones and the use studded winter tyres for bicycles (Swedish Transport Administration 2014). The analysis was based on all hospital reported crashes between 2007 and 2012 and showed that improved operation and maintenance (removal of loose gravel/leaves, and effective deicing) had the largest combined potential of addressing 35–45% of crashes. Also, bicycle winter tyres and protective jacket and trousers with built-in energy absorbing pads (for instance in the elbows or knees) showed high potential, 15–20% and up to 30%, respectively.

While this was a first attempt to estimate the potential of different countermeasures to address hospital-reported bicycle injuries, there were a number of limitations. The estimates were based on mass-data, which is a benefit as it includes a large number of cases. However, the level of detail is often not very high which can therefore lead to uncertainties in the estimates. Further, such estimates were made for all hospital reported crashes, regardless of severity, which means that estimates for more severe injuries were not provided. Another limitation was that the issue with double counting was not taken into account. In this specific case, double counting refer to when a bicycle injury could be addressed by more than one countermeasure. For example, a cyclist without a helmet loses control of the bicycle on an icy road, falls off and sustains a head injury. This head injury could potentially be prevented both by a helmet but also by improved maintenance with deicing. This issue of double counting is not purely methodological, but also has important practical implications. It is relevant also for the SPIs that are used today in Sweden to prioritize road safety work for bicycles as it is not known how big proportion of crashes these SPIs address together.

Strandroth et al. (2012) demonstrated the benefit of deriving a residual of crashes not addressed by existing countermeasures. The advantage of a logical reduction of crashes based on existing countermeasures makes it possible to investigate safety gaps. Thereby, crash characteristics that need to be addressed by future safety interventions can be identified. This has important practical implications that can help guide stakeholders where to prioritize their resources. This deriving of a residual of crashes has not yet been applied to bicycle crashes.

In summary, there are still limited studies based on in-depth bicycle crash data, reporting the potential of different countermeasures in Sweden, especially with regard to crashes resulting in non-fatal injuries with high risk of health-loss. Further, it is not known how the SPIs for safe cycling together address these crashes. Lastly, a description of a residual of bicycle crashes not addressed by existing countermeasures is lacking. These issues make it difficult to properly address and prioritize both existing as well as future interventions for bicycle safety.

Aim

The aim of the present article was to estimate the potential of different countermeasures to reduce crashes resulting in injuries with high risk of health-loss among cyclists in Sweden. A further aim was to describe the residual—that is, crashes that were not considered to be addressed by the analyzed countermeasures. A detailed description of these residual crashes is needed to point to where additional development of bicycle safety is needed.

Methods

Material

The present study was based on the same material previously used in Ohlin et al. (2019), which includes a detailed description of sampling methods and materials. A brief description is given below.

The main data source was the Swedish Traffic Accident Data Acquisition (Strada), which is a database with national coverage containing information from police-records and emergency care hospitals regarding road traffic crashes in Sweden. Crashes included in the national database must have occurred on the public road network and involve at least one injured person (Swedish Transport Agency 2016). In order to obtain more details regarding crash circumstances and the consequences of injuries, a questionnaire was sent to a sample of individuals above 15 years of age that had sustained specific injuries in bicycle crashes during the period January 2013–April 2017. These injuries had previously been identified as having higher risk of resulting in health loss (Ohlin et al. 2017; Ohlin et al. 2018) and included fractures to the hip and upper leg, to the lower leg and ankle, fractures of the upper arm, fractures and sprains of the shoulder, traumatic brain injuries (excluding mild concussions), and fractures and strains to the spine. Please see Ohlin et al. (2019) for further

Table 1. The potential of countermeasures considered in Step 1.

Countermeasure	%* and (*n*) of crashes addressed
Helmet use	2% (162)
Removal of loose gravel	3% (232) 14% (1042)
Deicing and removal of snow	8% (588)
Improved quality of road surface	1% (82)
Removal of leaves	1% (72)
Other maintenance of bicycle paths	1% (68)
Safe bicycle crossings	4% (288)
Passenger car crashworthiness	5% (342)
Sum of individual potentials	**24% (1834)**
Total without double counting	**22% (1684)**

*% of total *N* (7553).

details. In total 2,678 persons were invited to participate and the overall response rate was 36%. The response rate was similar for all included injuries. A total of 947 cases were available for analysis.

As mentioned in Ohlin et al. (2019), the sampling was made from injury groups of different sizes. Therefore, each individual case was weighted to represent the actual injury distribution in Strada. A weighting was assigned to each injured body region by dividing the number of included cases for each body region with the corresponding number of that body region in Strada from which the sample was drawn, multiplied with the inversed proportion of the included cases (see Ohlin et al. 2019 for further details, and Table A1 in the Online Appendix). Each individual was assigned a weighting based on their injured body region, resulting in a weighted total of 7,720 cases.

The rate of helmet wearing was 47%. The characteristics of the crashes are further described in Figure A1 in the Online Appendix. Crashes with unknown circumstances where excluded in the present analysis (2% of the material, $n = 167$) resulting in 7,553 weighted cases available for analysis.

Data analysis

Based on the weighted material, an analysis was carried out to estimate the potential of different countermeasures (i.e., the number of cases that could be prevented with a specific countermeasure). Basically, this was done by defining a target population for each countermeasure, as shown in Table A2 in the Online Appendix. For instance, single bicycle crashes involving loss-of-control (LoC) on snow or ice were considered to potentially be prevented by improved winter maintenance of bicycle paths. Another example, the potential of bicycle helmets was considered to be all crashes involving head injury and cyclist was not wearing a helmet at the time of the crash.

Further analysis was then performed to identify and describe the residual of cases that could not be prevented by the considered countermeasures. More specifically, the analysis was performed in four steps, as follows.

1. The potential of countermeasures currently included in the Swedish SPI was assessed, see Table A2 in the Online Appendix. These are use of bicycle helmets, good quality maintenance of bicycle paths (shared or separate) and safe bicycle crossings (Swedish Transport Administration 2018). While the current SPI for safe passenger cars only includes maximum rating for adult occupant protection as rated by Euro NCAP (Swedish Transport Administration 2018), the present study included VRU crashworthiness as part of the Swedish SPI for safe cars.
2. As a second step, the potential of countermeasures that could be described as “existing but not fully implemented” was assessed, see Table A2 in the Online Appendix. The basic idea was to assess the potential of countermeasures that could be rapidly implemented, with limited need of further research and development. These included, for example, existing vehicle technologies such as AEB with cyclist detection on passenger cars, improved and extended bicycle infrastructure, use of reflective clothing and studded tyres for bicycles.
3. The overall potential of all countermeasures assessed in Step 1 and Step 2 was calculated, thus giving a grand total without double counting. This step also calculated the overall potential of the countermeasures in Step 1 and five countermeasures in Step 2 that together would result in the highest potential, taking double counting into consideration.
4. Cases that were considered not to be addressed by any of the countermeasures included in Step 1 and Step 2 (i.e., the residual) were described in more detail in Step 4. This was done both by comparing the residual with the crash and individual “baseline” characteristics of all cases, as well as a description of specific detailed crash characteristics.

Thereby, the output from the analysis serves both as an estimation of the number of crashes/injured that could possibly be prevented, as well as a detailed description of the residual crashes that could not be prevented by the considered countermeasures.

Results

Step 1

The current Swedish SPIs that relate to safe cycling addressed 22% of the 7,553 crashes (Table 1). In some cases, more than one countermeasure was relevant resulting in an overlap of countermeasures in the same crash. Therefore, the sum of the individual potentials (i.e., with double counting) was 1,834 of 7,553 crashes (24%). Improved maintenance by deicing and removal of snow from bicycle infrastructure was found to have the highest potential (8%), followed by improved crashworthiness of passenger cars (5%) and safe bicycle crossings (4%).

Step 2

The greatest potential was found for AEB with cyclist detection for passenger cars (12%) followed by studded winter tyres for bicycles (12%) (Table 2). An additional 11% of crashes could be addressed if improved maintenance (e.g., deicing and removal of loose gravel) would extend to also include

Table 2. The potential of countermeasures considered in Step 2 (part 2).

Countermeasure	%* and (*n*) of crashes addressed
AEB with cyclist detection on passenger cars + other MV	12% (938) + 0.2% (17)
Improved underrun protection on HGVs + LGVs	0% (0) + 0.2% (14)
Electronic Stability Control of MVs	0.1% (8)
Bicycle technical inspection	1% (88)
Studded winter tyres for bicycles	12% (883)
Use of adult senior tricycle (improved bicycle stability)	3% (247)
Use of additional crash protection	0% (0)
Increased minimum passing distance	1% (72)
Improved conspicuity	0,2% (19)

*% of total *N* (7553).

Table 3. The potential of countermeasures considered in Step 2 (part 1).

Countermeasure	%* and (*n*) of crashes addressed
Improvement of curbstones	7% (534)
Separating from pedestrians	3.6% (272)
One-directional bicycle paths	2% (155)
Separate from MV	4.5% (351)
Improvement of fixed objects	2% (145)
Safe intersections	1% (89)
Improved design of construction work affecting bicycle infrastructure	3% (221)
Improved maintenance (all types) other than bicycle infrastructure in urban areas + rural areas	11% (795) + 2.5% (187)

*% of total *N* (7553).

Table 4. The overall potential of countermeasures considered in Step 1 and 2.

	%* and (*n*) of crashes addressed
Sum of individual potentials	67% (5035)
Total without double counting	56% (4227)
Total without double counting, including Step 1 safety improvements	64% (4852)

*% of total *N* (7553).

non-bicycle infrastructure in urban areas (Table 3). In total, it was found that the sum of the individual potentials of all safety improvements in Step 2 was 67% (Table 4). However, as a greater number of countermeasures was considered in Step 2, the overlap of different safety improvements was more pronounced than in Step 1 (e.g., improved maintenance, including deicing, would address the same crash population as studded winter tyres). When double counting is taken into account, the combined potential of the safety improvements in Step 2 was 56%. In total, taking double counting into consideration, all safety improvements from Step 1 and Step 2 could address 64% of all crashes (Table 4).

Step 3

An analysis was carried out to identify the combination of five different countermeasures in Step 2 that together with the countermeasures included in Step 1 would result in the highest overall potential (i.e., the combination with the smallest overlap). The analysis showed that the highest potential of 51% of crashes potentially addressed ($n = 3,888$) was given by the Step 1 countermeasures combined with the following ones:

- AEB with cyclist detection on passenger cars
- Improved maintenance in urban areas on non-bicycle infrastructure
- Improvement of curbstones
- Separation from motor vehicles
- Separation from pedestrians

However, it was also found that adding *improved design of construction work,* or *improved maintenance in rural areas* instead of *separation from pedestrians* had almost the same overall potential.

Step 4 - Residual crashes not addressed by considered countermeasures

As mentioned above, it was found that 36% of crashes could not be addressed by countermeasures included in the current Swedish SPIs (Step 1) and other existing but not fully implemented countermeasures (Step 2). Table 5 below shows the detailed characteristics of the residual crashes. Among the residual crashes, the majority (69%) were single bicycle crashes of which most were related to wheel locking during braking and losing balance at low speed or stationary. In Figure A3 in the Online Appendix, additional details of the residual crashes are presented.

Compared with the "baseline," consisting of all 7,553 weighted cases, there were few Bicycle-Motor Vehicle (MV) crashes among residual crashes, and a larger share of crashes involved another VRU (Table 6). 92% of Bicycle-MV crashes were considered to be addressed while only 31% of crashes with other VRUs were addressed. Further, the age distribution was similar in the residual crashes compared with the baseline. It was also found that a higher share of traumatic brain injuries and multiple injuries (which often included head injuries) were addressed (78% and 72%, respectively).

Table 5. Detailed description of residual crashes not addressed by any of the included countermeasures.

Single bicycle crashes (69% of residual crashes)	Collision with another cyclist (19% of residual crashes)	Collision with MV (4% of residual crashes)	Collision with pedestrian (3% of residual crashes)
Wheel locking due to hard braking	Non-bicycle infrastructure	Speed calming measures were already implemented	Crash occurred at intersection/junction
Losing balance at low speed or stationary involving people younger than 75 years	Crash occurred at intersection/junction	Speed of car reported to be <30 km/h	No bicycle/pedestrian infrastructure
Locking of wheels due to object (e.g., on a bag hanging on the steering) caught into the wheel	Crash occurred in an overtaking situation	Limited detection for AEB	Already separated bicycle path
Wheel getting caught in a tram (or similar) track	Rear-end crash	Cyclist crashed into side or rear of car	–
Falling while getting on/off the bike involving people younger than 75 years	–	–	–
The road surface was slippery because of rain	–	–	–

Table 6. Proportion of crashes potentially addressed divided by age group, injured body region, and crash type.

		% of crashes potentially addressed
Age group	≤25	86
	26–35	69
	36–45	59
	46–55	62
	56–64	63
	65–74	58
	≥75	76
Injured body region	Hip & upper leg	57
	Lower leg & ankle	64
	Multiple	72
	Traumatic brain injury	78
	Shoulder & upper arm	63
	Spine & back	63
Crash type	Bicycle-other VRU	31
	Bicycle-MV	92
	Single bicycle crash	64
	Other	18
Total		64

Discussion

The present study combined Swedish hospital reports with a questionnaire to assess the potential of different countermeasures in non-fatal bicycle crashes involving injuries with high risk of health loss. It was found that 36% of crashes could not be addressed by any of the countermeasures included in the current Swedish SPIs or other existing but not fully implemented countermeasures. The current Swedish SPIs only addressed 22% of the crashes. Compared to the estimates reported in the STA bicycle strategy, similar results were found regarding the countermeasures with highest potential (not considering double counting) where operation and maintenance, adjustment of curbstones as well as the use of studded winter tyres showed high potential in both studies. As the present paper only included injuries with higher risk of health-loss, while the STA estimates included all hospital reported crashes, these similarities indicate that crashes involving injuries with higher risk of health-loss do not differ from other bicycle crashes, a finding previously reported by Ohlin et al. (2019).

However, some differences can be found compared with fatal bicycle crashes. Kullgren et al. (2019) used a similar approach to assess the potential of different countermeasures to prevent cyclist fatalities on national and municipal roads in Sweden between 2006 and 2016 ($n = 184$). A majority of these crashes were collisions with motor vehicles, mostly involving passenger cars (46%), while only 21% were single bicycle crashes. Therefore, the potential of different safety systems in cars (mainly AEB) was found to be large, approximately 60%, compared with 12% in the present study (Kullgren et al. 2019). Countermeasures related to infrastructure showed high potential, which was also the case for fatal bicycle crashes (Folksam 2018). However, there was a difference related to maintenance. The present study suggest that improved maintenance of bicycle infrastructure could address 14% of crashes, whereas only 2% of fatal crashes would be addressed (Folksam 2018). Another difference was related to helmet use, where as many as 37% of cyclist fatalities could have been prevented with a helmet (Folksam 2018). In the present study, only 2% of crashes would be addressed with a helmet. This low potential could seem to be an unexpected result; however it can be explained by a number of reasons. Firstly, it should be kept in mind that specific injuries were selected in Ohlin et al. (2019), and also that traumatic brain injuries had a lower weighting, due to the fact that this type of injury (fortunately) is relatively rare. Further, the helmet use rate was quite high among the included cases in the present study (47%), whereas it was only 25% among the fatal crashes investigated in Kullgren et al. (2019).

An interesting finding in the present study was that only 5% of crashes would be addressed by speed calming measures. This is, however, not very surprising considering that most crashes included were single bicycle crashes, and the fact that at least 50% of the cyclists reported the speed of the MV to be below 30 km/h, which is considered to be a safe speed. Folksam (2018) showed that there had been no cyclist fatalities in Sweden on a bicycle crossing with speed calming measures implemented. However, as indicated by this study, and suggested by Kröyer (2015), 30 km/h might not be sufficiently low to prevent severe injuries among pedestrians and cyclists.

Overall, 92% of bicycle-motor vehicle crashes could potentially be addressed by existing countermeasures, mainly by passenger car technology (AEB with cyclist detection). The implementation of such safety systems is increasing, largely as a result of Euro NCAP, and in Sweden at least 38% of new cars were sold with AEB for VRU in 2017, which is almost double compared with 20% in 2016 (Ydenius and Kullgren 2019). Of course, it will take a long time before all vehicles on the roads are fitted with AEB VRU, and efforts to increase the speed of implementation should be encouraged. However, with this technology already existing, innovation and development of additional countermeasures to improve safety for bicyclists should focus on single bicycle crashes.

Single bicycle crash was the most common crash type (68%), similar to other studies of hospital reported crashes in Sweden (e.g., Swedish Transport Administration 2014). In recent literature, the impact from single bicycle crash has been increasingly recognized, also internationally. In the Netherlands, 50% of the total burden of serious road traffic injuries in 2011 were attributed to bicycle crashes without motor vehicle involvement (Weijermars et al. 2016). In Australia, 56% of cyclists admitted to hospital following a bicycle crash were injured in single bicycle crashes (Beck et al. 2016). In a following study, Beck et al. (2019) further investigated circumstances in 62 single bicycle crashes and found that 37% were loss-of-control events (commonly involving sudden braking), 19% resulted from interaction with tram tracks, 13% resulted from striking a pothole or object, 10% resulted from mechanical issues with the bicycle and 21% were classified as other events. In the present study, the countermeasures with the highest potential to address single bicycle crashes were improved maintenance also on non-bicycle infrastructure, improved maintenance (deicing and removal of snow) on bicycle paths, use of studded tyres on bicycles and improvement of curbstones. Considering that the bicycle infrastructure and weather conditions may differ between Sweden and Australia, different countermeasures might be required to reduce single bicycle crashes in Australia, compared with Sweden.

However, among loss-of-control events in Australia, sudden braking was common, which was also the case among the residual crashes in the present study (see description of residual crashes in the Online Appendix). This suggests that the development of improved braking stability for bicycles should be a priority for bicycle manufacturers.

The present study has a number of limitations that need to be discussed. First of all, it should be noted that the assessments of potentials were partly based on self-reported data, and not on actual crash reconstructions as, for instance, in Folksam (2018) and Kullgren et al. (2019). While the use of self-reported data in traffic safety can be affected, for example, by social desirability (af Wåhlberg et al. 2010), it should be noted that the crashes in the present study were hospital-reported. Further, the questionnaire was designed to understand a sequence of events that can characterize bicycle crashes, rather than the presence of violations or similar aspects, which intuitively might be more strongly affected by social desirability. While efforts were made to design the questionnaire as clearly as possible, it cannot be excluded that some participants might have misinterpreted some of the questions. Furthermore, depending on how much information provided by the respondent, there always exist a certain degree of subjectivity when interpreting a course of events or which factors that contributed to the crash. Yet, it should be noted that some self-reported data may be more sensitive than others, for example, the estimation of the speed of the motor vehicle, although it is interesting to note that at least 50% of the cyclists reported speeds below 30 km/h (Ohlin et al. 2019).

A further limitation is that the possible synergy effects of different countermeasures were not assessed. For example, previous research (Ohlin et al. 2017) indicates that the combined benefits of speed management, bicycle helmets and high rating in the Euro NCAP pedestrian protection test is larger than the sum of the individual reductions of injuries among cyclists hit by cars. This could suggest that the overall potential of the countermeasures presented in this paper (even without double counting) could be an underestimation of the actual potentials. While this is a clear limitation, it is important to stress that such assessments are difficult with this kind of material in a case-by-case retrospective analysis. Also, it should be noted that the current paper analyzed potentials of countermeasures - not their real-life effectiveness. The difference between these two can be illustrated with an example. It could be argued that AEB with cyclist detection, as suggested by Ohlin et al. (2017), would reduce impact speed and thereby influence the effectiveness of the helmet. However, the potential of helmets, as assessed in this article, would still be unchanged: that is, any head injury sustained without a helmet. So clearly, whether the combined potential of two countermeasures differs from the individual potentials or not, also depends on how the target populations for the countermeasures are defined.

In the present study, it was not possible to take into account any possible behavioral adaptation that could, at least theoretically, follow the implementation of certain countermeasures. As mentioned above, it is difficult to take this into account in a retrospective case-by-case analysis. For instance, it could be argued that improved winter maintenance (or use of studded winter tyres) could prevent loss-of-control crashes, but at the same time could also lead to higher riding speeds and thereby contribute to a “new” set of crashes. While these aspects could lead to an overestimation of the potentials of countermeasures, it should again be noted that the present paper aimed at assessing the potential of countermeasures, not their real-life effectiveness.

The results are based on a sample with 36% response-rate. The response-rate was lower among those aged $\leq$25 years (18%), and among those whose crash occurred 2013–2014 (28%). However, the response rate was similar for men and women (35% and 37%, respectively) and across different injured body regions (Table A3 in the Online Appendix), suggesting that no bias from the type of injury influenced the results. As the focus was to investigate crashes involving specific injuries, the results should be regarded as representative of the study population. Please see Ohlin et al. (2019) for further elaborations on response-rates and comparisons between respondents and non-respondents.

Finally, it is clear that the choice of countermeasures included in the analysis could be further discussed. Despite that the list in Step 2 is quite extensive, other or additional countermeasures could have been considered. For example, lowered urban speed limits. Unfortunately, speed limits are not included in Swedish hospital reports, and the only way to fully assess the potential of lowered speed limits would have been merging the present dataset with the National Road Database (NVDB). Yet, it should be noted that in the present material the collision speed was estimated to be over 40 km/h in around 20% of the crashes involving a motor vehicle ($n = 239$; Ohlin et al. 2019), which suggests that the potential of lowering urban speed limits from 50 to 40 km/h would be limited.

Clearly, the potential generalizability of the present results to other jurisdictions need to be discussed. While it could be argued that the safety of the road infrastructure and the nature of cycling in Sweden would not be too different from other countries in Northern Europe, it is evident that the present results may not apply to all regions of the world. Therefore, it is of great importance that road authorities perform similar analyses in order to align their road safety management and priorities according to the characteristics of the bicycle crashes in their specific jurisdiction.

In conclusion, compared with fatal crashes that involve a majority of bicycle-car crashes, the crashes leading to health-loss are mostly single bicycle crashes. Therefore, innovation and development of additional countermeasures to improve safety for bicyclists should focus on single bicycle crashes.

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